The Marvin recorder gave a very perfect record, which is shown in the accompanying photograph of two sheets covering the two-week period, from noon December 14, to noon December 28.

The wind during the entire storm held steadily from S. to SSE., with an unusually high velocity, running 40, 50, and 60 miles per hour, reaching a maximum for a few minutes at one time of 80 miles per hour.

The temperature ranged from 40° to 45° day and night, dropping once to 22°, rising to the former figures again in a short time.

The runoff was rapid and as soon as the weather cleared the Santa Ana, San Gabriel, and Los Angeles Rivers could be plainly seen from the mountain top, spreading their waters out over the level lands adjacent to those streams, inundating many low-lying farms for a distance of 20 or 30 miles inland from the sea.

This storm came after a long period of dry weather, which is characteristic of this region. Only 1.48 inches had fallen since May 23, 1921.

A simple computation helps one to realize what an enormous amount of water falls to the ground from the clouds during such a storm. A fall of 29.38 inches of rain means 152.5 pounds of water to every square foot of surface, 33,214 tons per acre and 21,257,280 tons per square mile.

STORM OF NOVEMBER 19–22 IN OREGON, WASHINGTON, AND IDAHO, AND STORMY PERIOD FOLLOWING.

551.515(795)(797)(796)

EDWARD LANSING WELLS, Meteorologist.

[Weather Bureau, Portland, Oreg., Jan. 9, 1922.]

A period of unusually stormy weather in the Pacific Northwest began with a sudden drop in temperature in eastern Washington on November 19, 1921, and closed with high wind and a remarkable rise in pressure on December 1 and 2. Prominent features of this stormy period were: a destructive ice storm from the vicinity of Portland eastward to the Columbia River Gorge on November 19 and 20; a very heavy fall of sleet and snow along the middle Columbia, and of snow in northeastern Oregon, southeastern Washington, and north-central Idaho, and phenomenally heavy rainfall west of the Cascades, from November 19 to 22; a rapid rise in temperature beginning at Portland on the 21st and reaching interior points on the 22d; and the continuance of mild, rainy weather during the remainder of November.

Chart E. L. W.–I (upper map) shows the weather map of the morning of November 18. Two well-defined areas of high pressure are apparent, one, of a continental type, central in the interior of western Canada, and carrying low temperature, and the other central off the northern California coast, and varying mild temperature, with a shallow trough of low pressure between. The lower map shows the center of the continental anticyclone to have advanced to eastern Montana, the trough of low pressure to have moved somewhat southward, and the coast high-pressure area to have remained nearly stationary. The temperatures in the immediate vicinity of the continental high had fallen rapidly. At Spokane, Wash., a cold wave occurred, the temperature falling to −1°. This is the earliest zero weather of record at that place.

Some snow fell in eastern Washington and Oregon and northern Idaho on the 17th, but the heavy snowfall began on the evening of the 18th and continued until the 21st. At Lewiston, Idaho, the snowfall amounted to 15.9 inches, which is the greatest November snowfall of record, and is within half an inch of the average annual snowfall for that place. At Walla Walla, Wash., the snowfall amounted to 19.9 inches, which is the greatest November snowfall of record at that place. On the evening of the 20th the total depth of snow on the ground at Walla Walla was 18.2 inches, which is, with one exception, the greatest depth of record at Walla Walla.

Along the middle reaches of the Columbia River the snowfall was greater, reaching a total of 54 inches of snow and sleet at The Dalles, Oreg.

In the gorge where the Columbia River passes through the Cascade Mountains the precipitation was largely in the form of sleet, which rolled down the steep slopes and accumulated many feet in depth in places on the Columbia River Highway and on the tracks of the O.-W. R. & N. Co., and the S. P. & S. R. R. Co. Many automobiles and several trains were stalled. Railroad service was restored in a few days, but at this writing, January 9, the highway is still blocked. The tremendous pressure of the masses of frozen sleet sliding down into the gorge caused some damage to the reinforced concrete viaducts on the highway.

From the Columbia River gorge to the lower Willamette Valley the storm took the form of unusually heavy rain, partly freezing as it fell, forming a heavy coating of ice on trees, poles, wires, and roofs. Sleet and ice were experienced to some extent over large areas in eastern and southern Washington and northern Oregon, and to a limited extent in north-central Idaho, but the deposit of ice was greatest from the Columbia River gorge to the vicinity of Portland. Street-car service was obstructed, power, telephone, and telegraph lines running east from Portland were almost completely ruined, and at one time 9,000 telephones in Portland were out of commission.

The lowest temperature reached at the Weather Bureau office in Portland was 29°, on the 20th, and by the evening of the 20th the temperature had risen above the freezing point and the ice in the business district had disappeared. In the eastern portion of the city it did not disappear till the afternoon of the 21st.

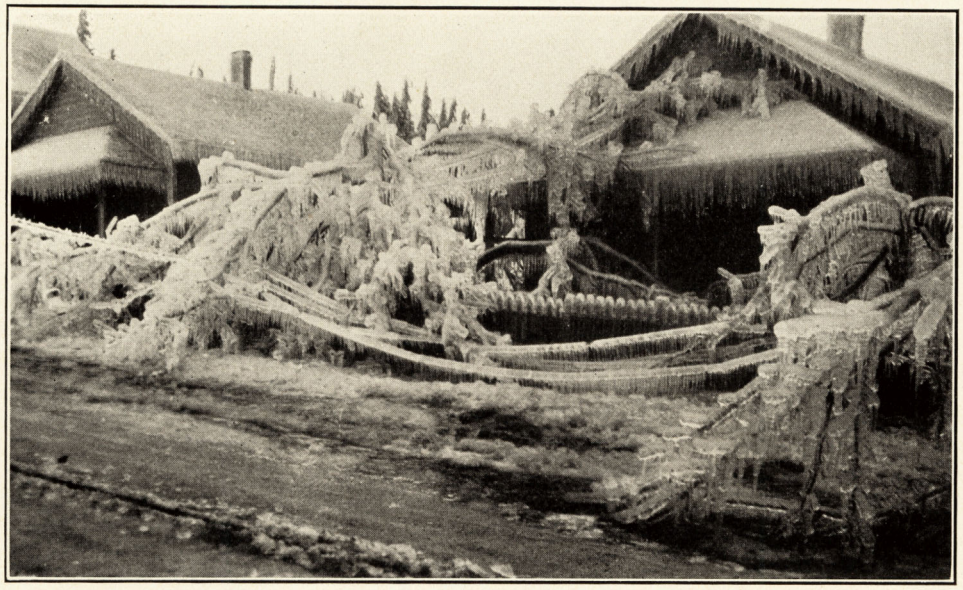
During the prevalence of the ice storm the wind at Portland was almost constantly from the east. Shortly before 4 p. m. on the 21st it was noted that the lower clouds, which had been moving from the east, were moving rapidly from the southwest, and in a few minutes the wind changed to south, increasing in force. In half an hour the temperature had risen from 40° to 56°.

This sudden rise in temperature reached eastern Washington, northeastern Oregon, and northern Idaho about 12 hours later, but was not felt in southern Oregon, southeastern Oregon, southern Idaho, nor on the coast. Thermograph traces from selected stations are shown in figure 1. The rise in temperature was greatest at Walla Walla, Wash., amounting to 32° in five hours.

Figure 2 shows the distribution of precipitation in Oregon for the four-day period, November 19–22. The precipitation reached a maximum of 13.03 inches at Zigzag Ranger Station, near Welches, on the west slope of Mount Hood, at an elevation of 1,435 feet.

At that place there was only 1 inch of snowfall, at and Government Camp, the highest station in northwestern Oregon, elevation 3,890 feet, the total snowfall for the

(To face p. 661.)



FIGS. 4-5.—Effects of ice storm near Portland, Oreg.

4 days was only 31 inches, and the total depth of snow on the ground at Government Camp decreased from 54 inches on the 19th to 8 inches on the 21st, while at The Dalles, elevation 96 feet, the fall of snow and sleet amounted to 54 inches. At Government Camp the lowest temperature during the period was 28°, while at The Dalles the lowest was 19°.

The charts and records indicate that during the storm there were two well-defined opposing currents of air; one a cold one, blowing out from the continental high, and the other a mild, moist one, blowing in from the ocean. The cold current, being heavier, underran the mild, moist current. Elevation of the moist current, due to the cold current beneath, and to the mass of the Cascade Mountains, cooled it sufficiently to cause rapid condensation, but not until it had advanced to a considerable distance inland was it sufficiently cooled to form snow. Near the coast and on the western slope of the Cascade Mountains the precipitation occurred as rain. From the lower Willamette Valley eastward to the Columbia River Gorge the precipitation reached the ground as rain, but in entering the cold easterly current it was so cooled that it froze as it struck, forming a heavy coating of ice on exposed surfaces. In the Gorge and over parts of the middle Columbia Valley, rain falling through the cold lower stratum was frozen into small globes of ice, which, to quote Mr. Samuel C. Lancaster, builder of the Columbia River Highway, "rolled down the slopes like wheat from a hopper." Farther inland the upper current became sufficiently cooled so that precipitation occurred as snow.

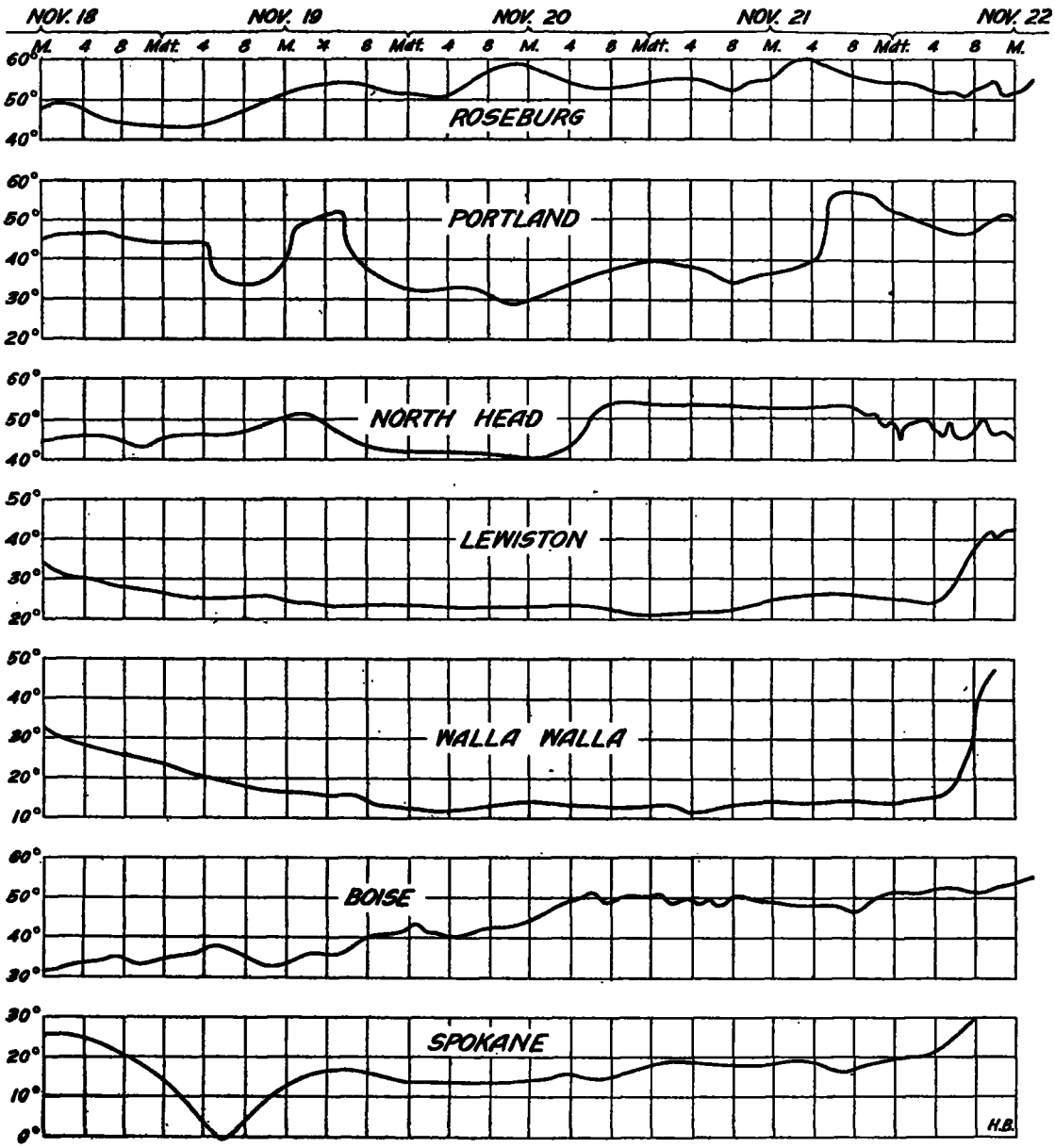
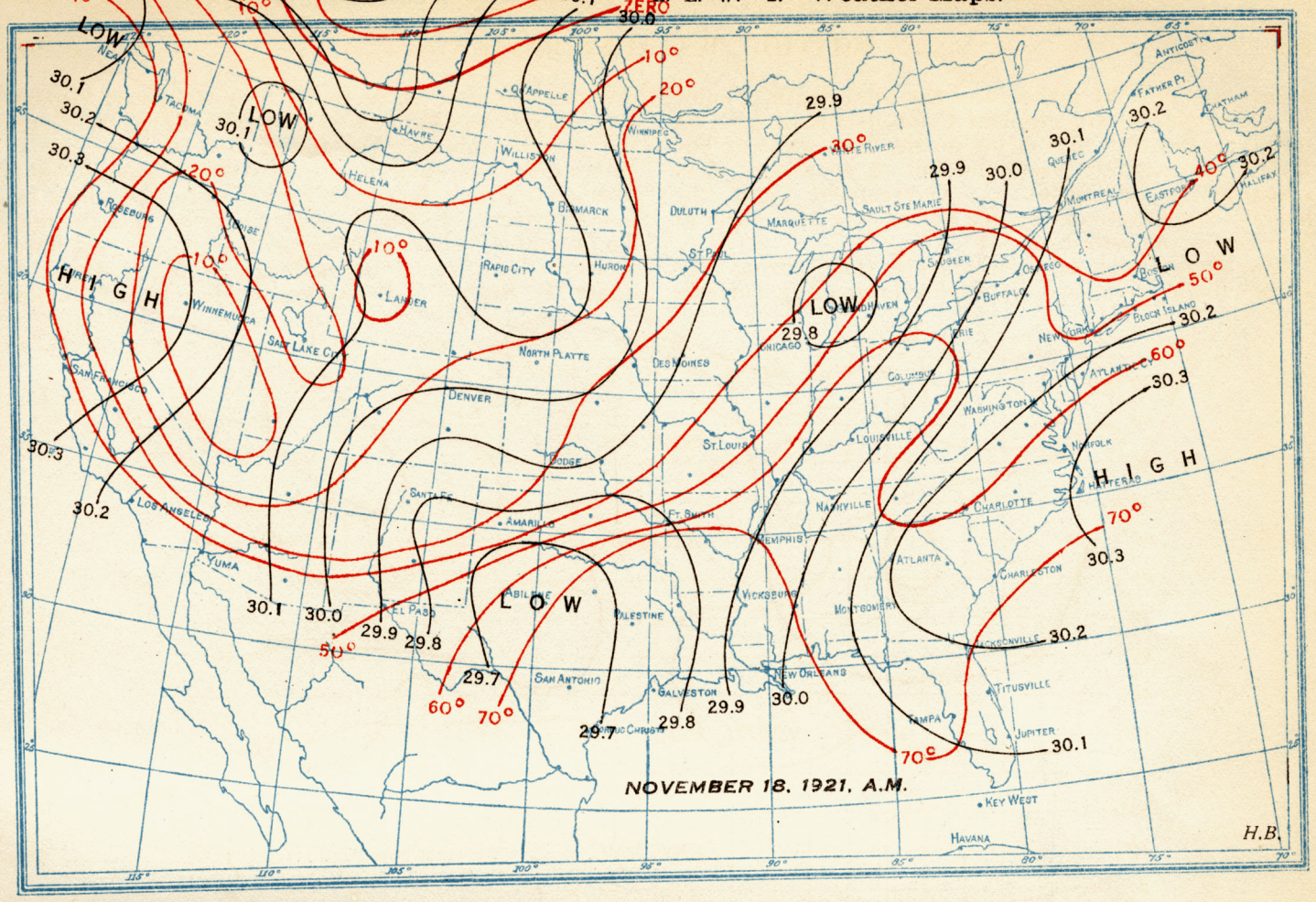


FIG. 1.—Thermograph traces from selected stations, Nov. 19-22, 1921.

Referring again to figure 1, it will be noted that during a large part of the period under discussion, Roseburg, Oreg., and North Head, Wash., had the mild temperature typical of winds from the ocean; at Boise, Idaho, the temperature rose gradually to about the same degree and then remained nearly constant; Spokane, Wash.; Walla Walla, Wash., and Lewiston, Idaho, had low


HIGH
LOW
LOW
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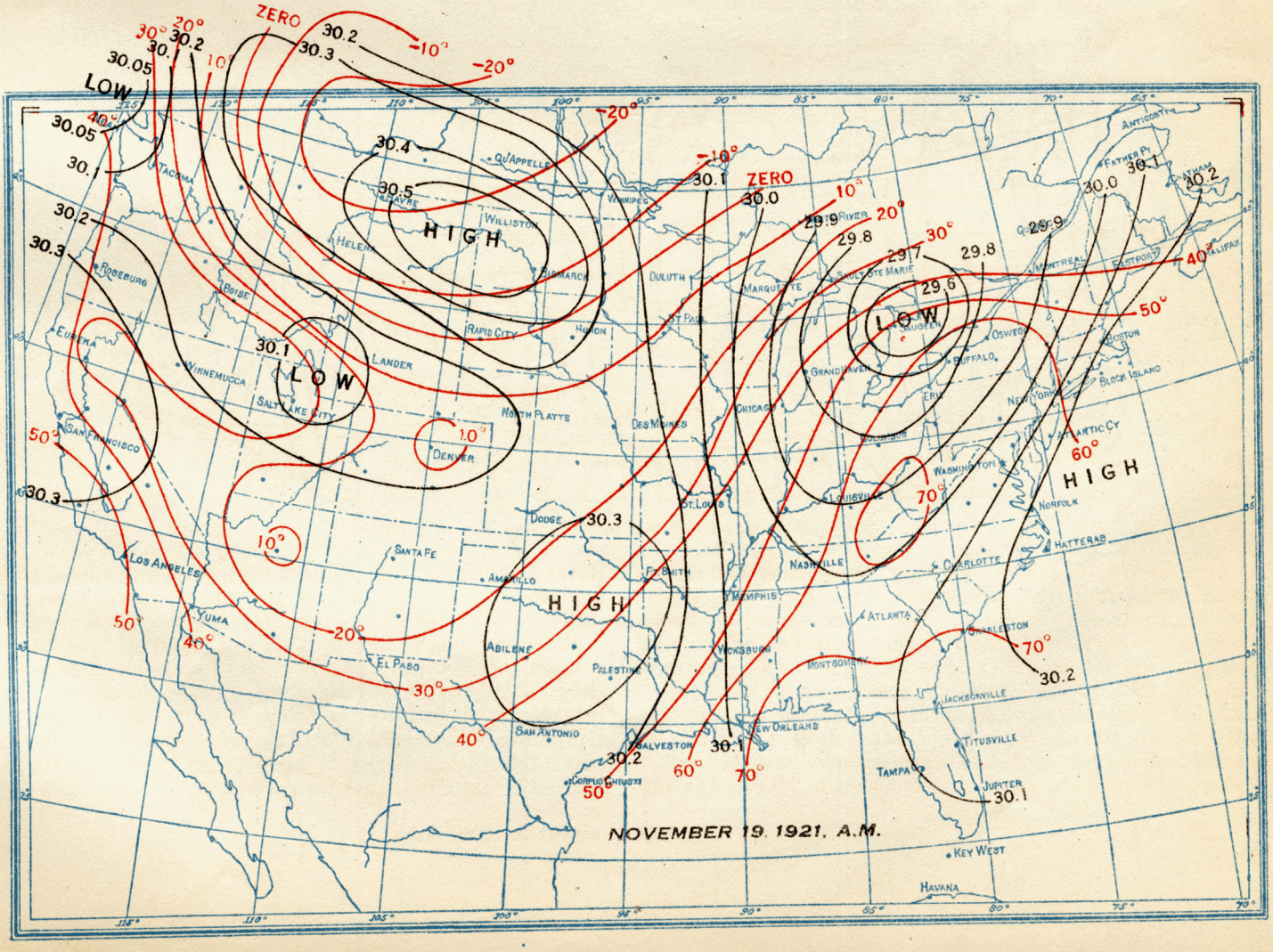
NOVEMBER 18. 1921. A.M.
H.B.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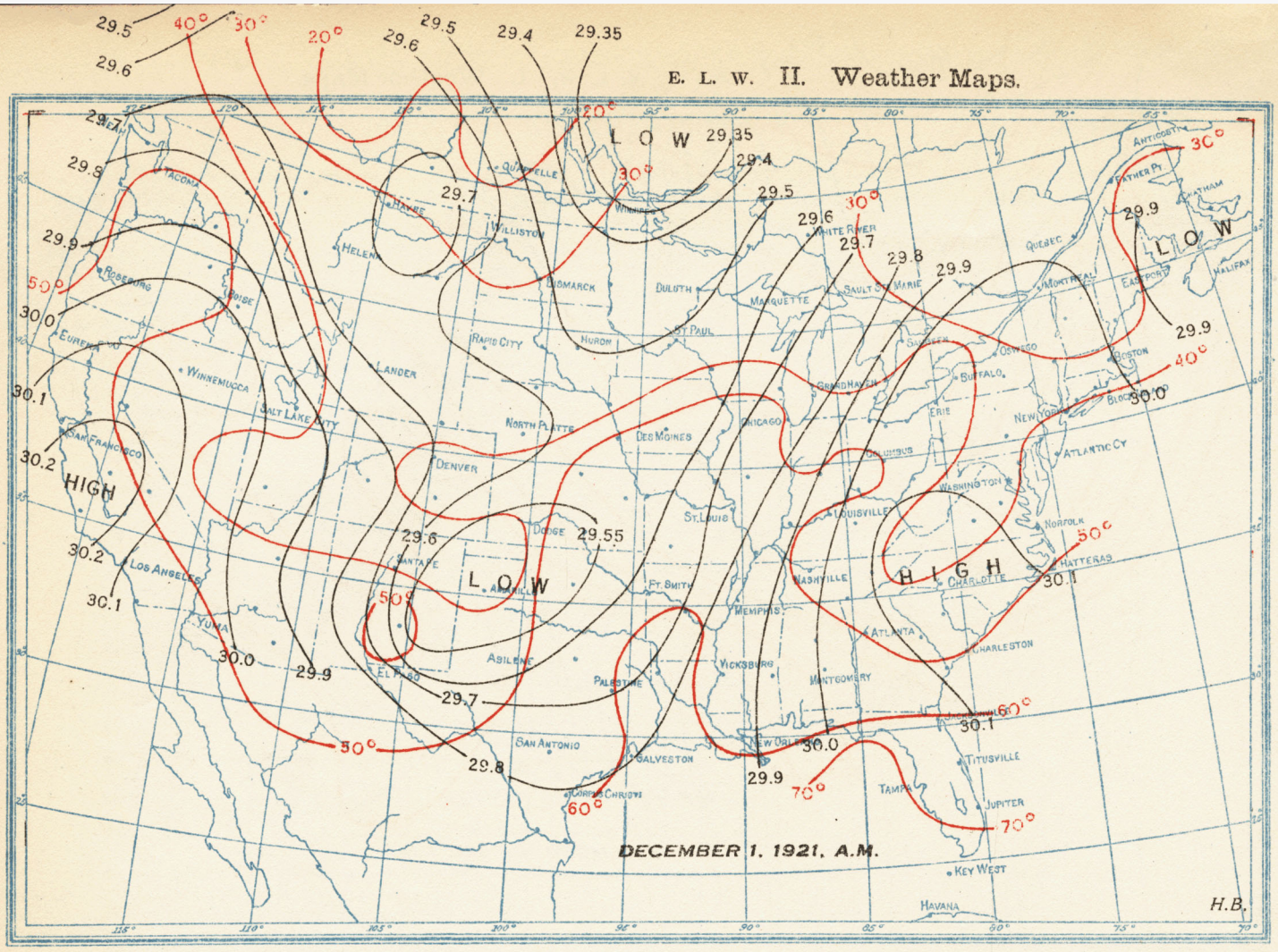
LOW
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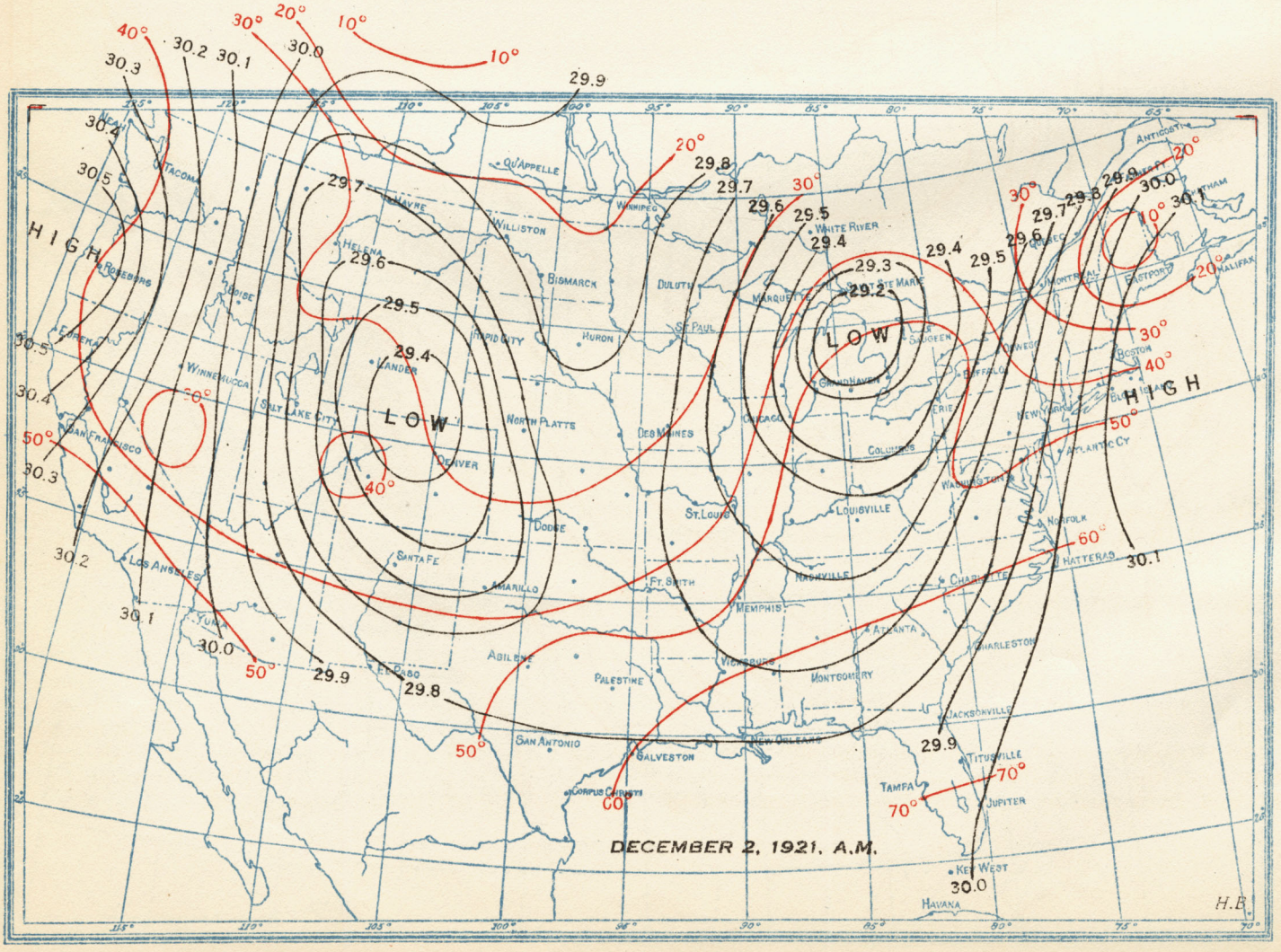
LOW
HIGH
LOW
DECEMBER 1, 1921, A.M.
H.B.


HIGH
LOW
HIGH
DECEMBER 2, 1921, A.M.
H.B.

temperature, which was quite uniform except for the sudden fall and subsequent rise at Spokane on the 19th.

Portland, being near the western end of the Columbia River Gorge, where the conflict between the two currents was most active, was part of the time under the influence of one current and part of the time under the influence of the other. Up to 4 a. m. on the 19th the wind was southwest and south, and the temperature was nearly the same as at Roseburg and North Head. At 4 a. m. on the 19th the wind changed to east and the temperature fell rapidly. Shortly after noon the wind went to south and the temperature again approached that of Roseburg and North Head, ice that had begun to form in the eastern portion of the city disappeared, and it was believed that the danger of a serious ice storm had passed. At 6 p. m. the wind went to northwest and the temperature again fell very rapidly. By 11 p. m. the wind was northeast and by 1 a. m. it was east. When the wind changed to south at 4 p. m. on the 21st the temperature quickly rose to approximately that of Roseburg and North Head.

The remainder of the month was unusually mild and rainy over the entire Pacific Northwest. Runoff from rain and from melting snow in the mountains caused rapid rises in most of the rivers in western Oregon and Washington. Flood stages were exceeded in the Willamette, Yamhill, Clackamas, McKenzie, and Santiam Rivers, and considerable damage was done by the overflow of the Santiam River near where it empties into the Willamette.

This period of unusually stormy weather came to a close in the opening days of December with the rapid movement inland of an area of very low pressure, which was closely followed by one of the most pronounced areas of high pressure ever known in this section. This movement is shown in figure 3, which gives the barograph traces for representative stations, and in Chart E. L. W. II, which presents the weather maps for the mornings of December 1 and 2.

This movement was attended by high winds, which in some places caused much damage to trees, wires, and roofs. At Portland the wind reached a velocity of 42 miles an hour, from the west. This is the highest velocity recorded at Portland since the anemometer was placed in its present location. At North Head the wind reached a maximum velocity of 90 miles from the northwest. This is the highest velocity ever recorded at North Head from the northwest.

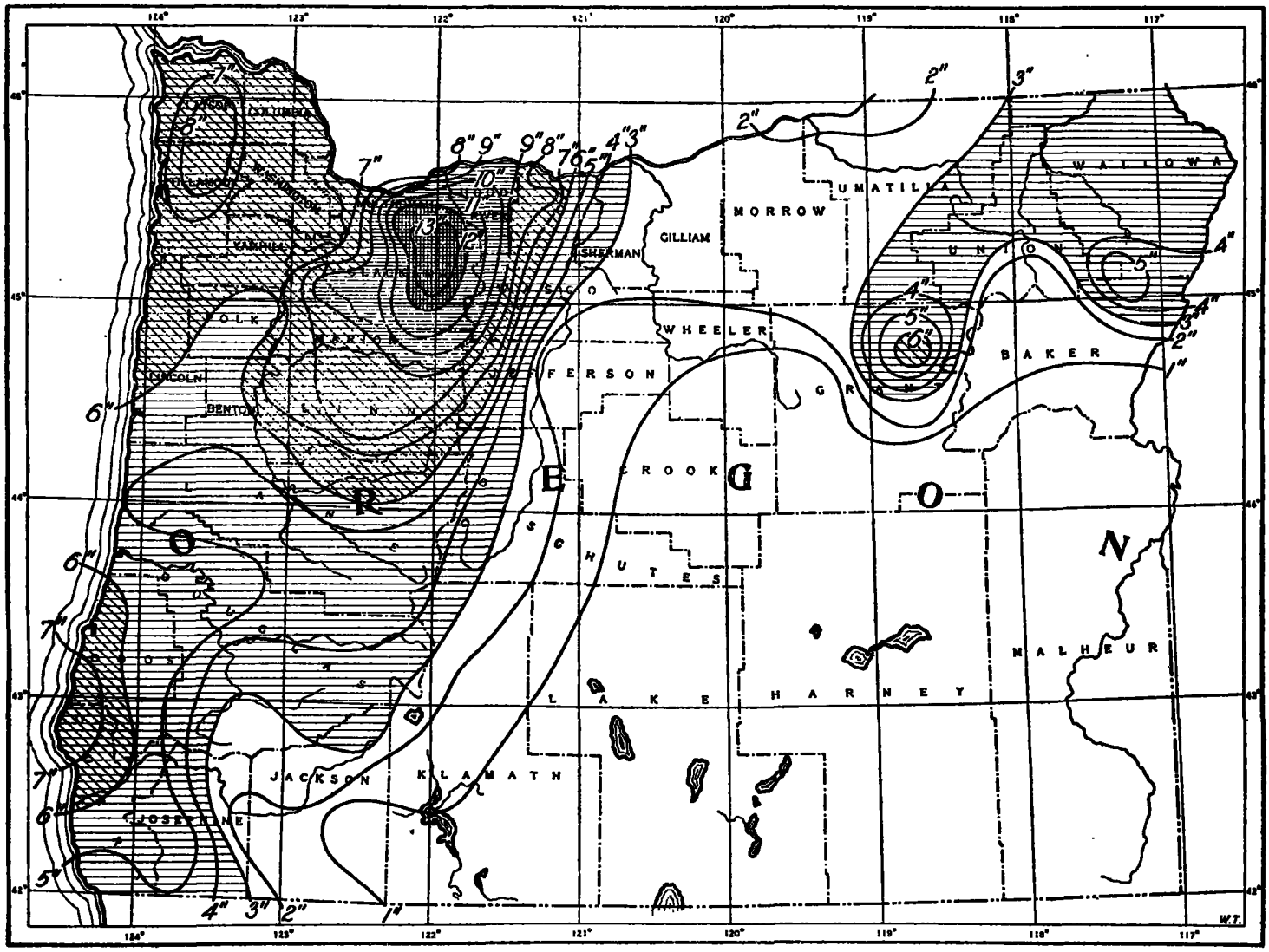


FIG. 2.—Distribution of precipitation in Oregon, Nov. 19-22, 1921.

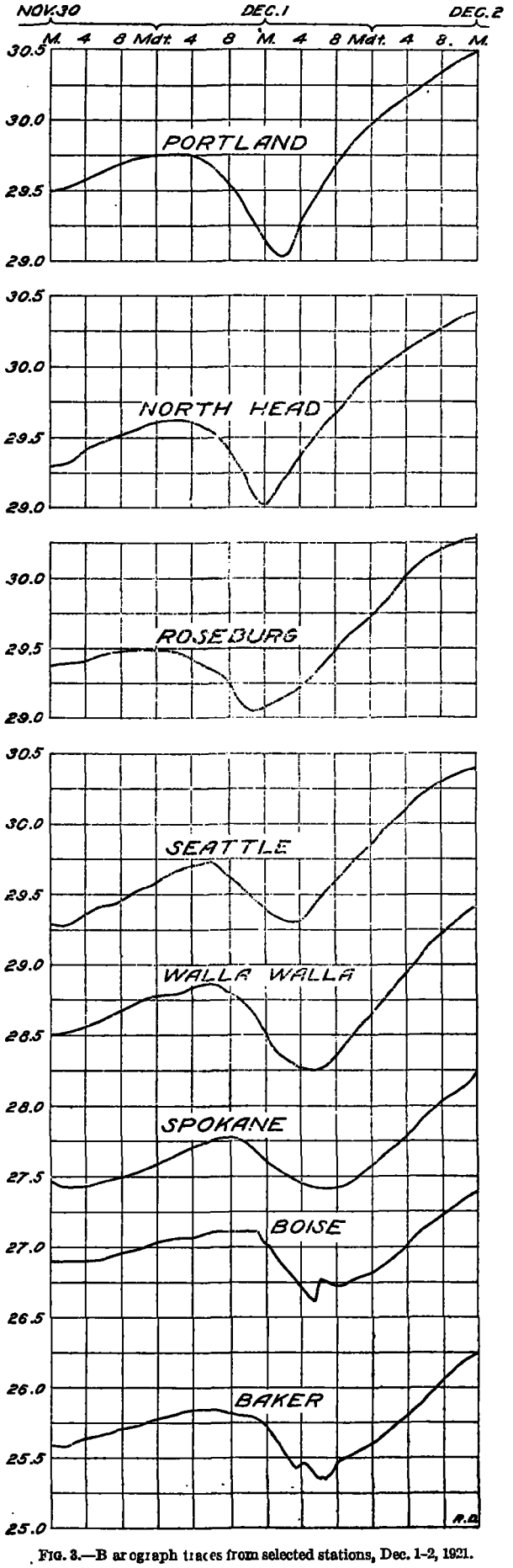


FIG. 3.—Barograph traces from selected stations, Dec. 1-2, 1921.

The official in charge of the Weather Bureau office at Roseburg reports that wild geese were heard all night on November 30–December 1, going south, and apparently flying low.

Table I gives some of the more important weather data for the period under discussion.

TABLE 1.—*Meteorological data for various stations, Nov. 19–22 and Dec. 1–3, 1921.*

	Tatoosh Island, Wash.	Seattle, Wash.	North Head, Wash.	Spokane, Wash.	Walla Walla, Wash.	Lewiston, Idaho.	Boise, Idaho.	Baker, Oreg.	Roseburg, Oreg.	Portland, Oreg.
Greatest precipitation in 24 hours, Nov. 19–22	2.61	1.57	1.51	0.16	1.21	0.88	*1.00	1.08	2.09	*4.43
Total snowfall Nov. 19–22	T.	7.3	0	7.4	*19.9	*15.9	0.4	6.3	0	0
Lowest sea-level pressure, Dec. 1	.....	29.43	29.26	29.40	29.33	29.38	29.41	29.42	29.40	29.22
Highest sea-level pressure, Dec. 2–3	†30.78	†30.83	30.76	30.79	30.78	30.84	30.79	30.83	30.74	30.77
Maximum velocity of wind, Dec. 1–2	56	39	90	29	27	31	31	24	40	24

*Greatest on record for November. †Highest on record.

551.515 (767)

THE CLARKEDALE, ARK., TORNADO OF DECEMBER 23, 1921.

By J. H. SCOTT, Meteorologist.

[Weather Bureau, Memphis, Tenn., Jan. 12, 1922.]

The tornado developed very near the center of a narrow but rather intense troughlike depression between areas of high pressure which crested over the Dakotas and off the South Atlantic coast, respectively, the one over the Dakotas being of the greater intensity.

The temperature was above 70° F. and the atmosphere was rather oppressive, the highest temperature of the month occurring at Memphis on that day; the temperature gradient to the northwest was rather steep. The day was cloudy, with strato-cumulus and stratus from the south and southwest, moving with the wind at the surface. There had been no rain at Memphis, aside from a trace in the early morning, and none fell at Memphis during the storm, though a heavy downpour occurred along the storm track coincident with or immediately following the storm, which was accompanied with lightning and thunder. The lightning was visible in Memphis, but no thunder was heard. Although the storm passed within less than 20 miles of Memphis, it produced no appreciable effect on the pressure, temperature, or wind at the latter place.

The tornado apparently originated 5 or 6 miles southwest of Clarkedale, Ark., but did not attain greatly destructive force until it struck the Booker farm, some 2 miles from Clarkedale, where several buildings were wrecked and two persons were killed. Continuing its northeastward course, the tornado struck the town of Clarkedale squarely, wrecking the majority of the buildings, including the large brick plantation store of Banks & Danner, where 40 or 50 persons were doing their Christmas shopping or had taken refuge from the advancing storm. One white and three colored men lost their lives in the collapse of this building. The total death list from the storm was 6, while the seriously injured numbered about 15. Besides the plantation store, a large cotton gin, several warehouses, a number of substantial residences, and 40 or more plantation cabins were wrecked. The cabins were of frail construction,